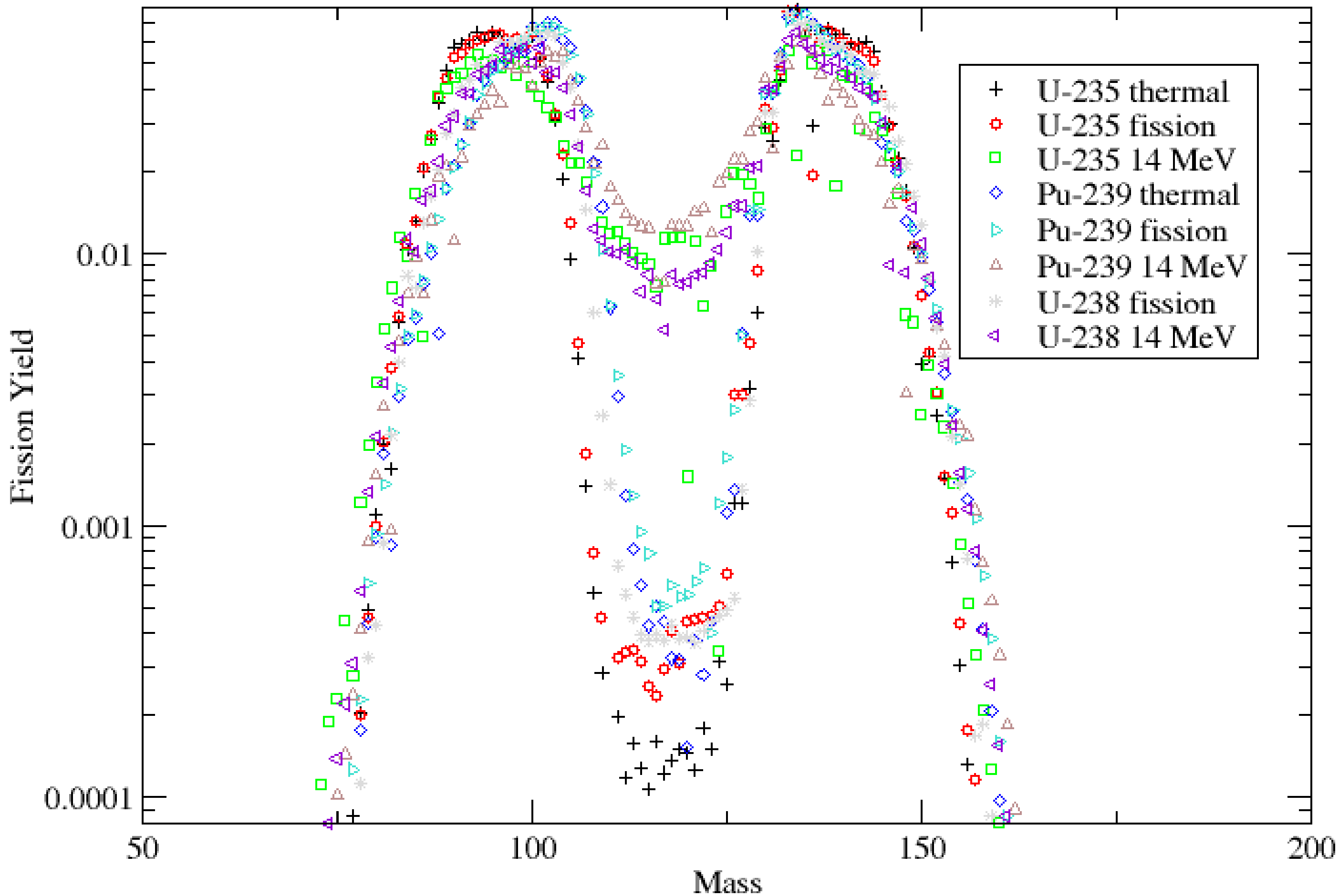
Utilization of NCERC in Support of Nuclear Forensics Measurements

15March2016

ENDF Fission Chain Yields



Scientific Background: R-values

- An R-value is a ratio of activity ratios.
- In both cases the denominator is a reference, namely ^{99}Mo and thermal neutron fission of ^{235}U.
- The advantage of this ratio is that most systematic errors are cancelled. For example, detector efficiency, branching ratios, etc.
- R-values can be used to determine fuel composition and neutron energy.

$$R_{99} = \frac{A_i / A_{99}}{A_{iT}^{U235} / A_{99T}^{U235}}$$

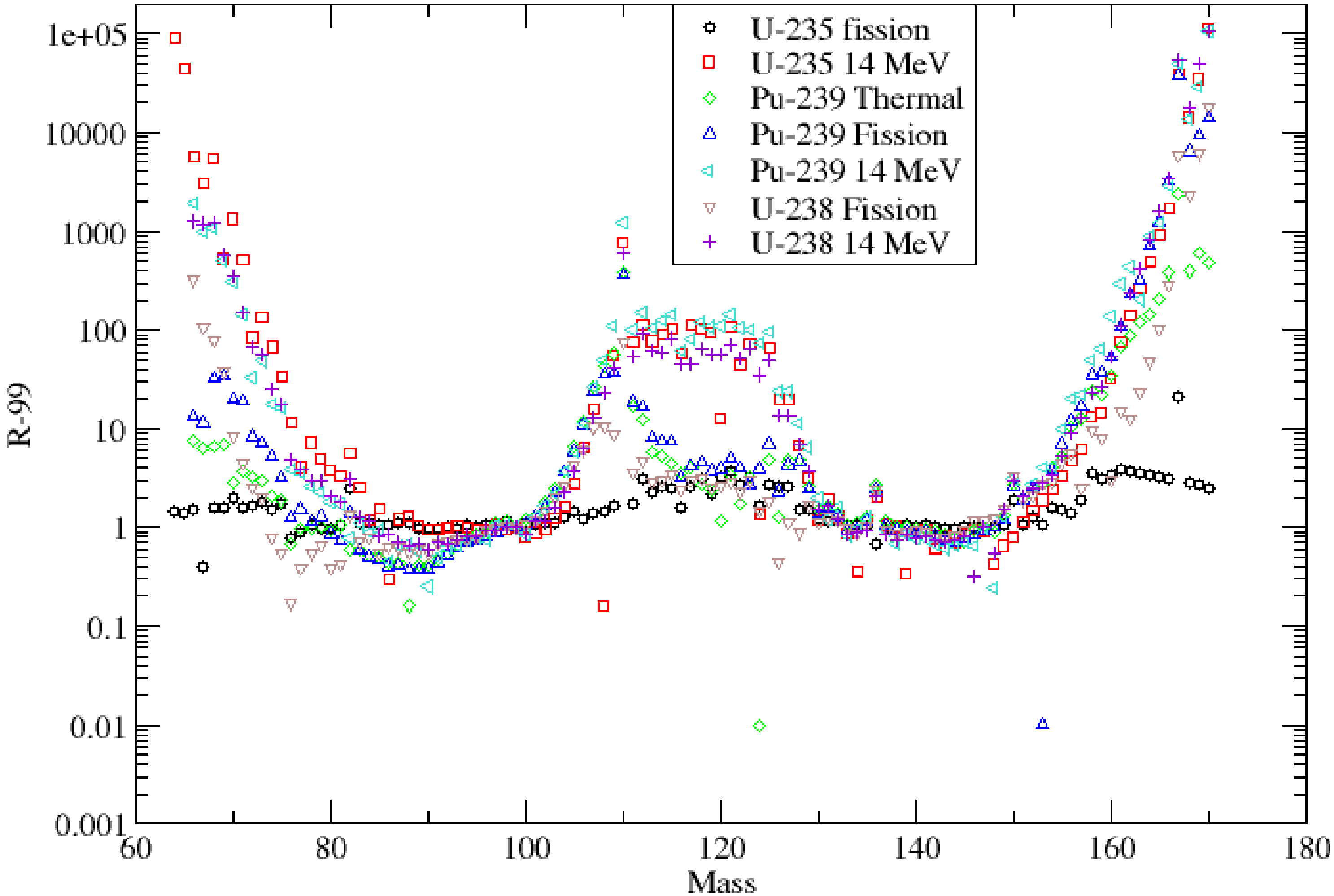
$$R_{99} = \frac{\varepsilon_i f_i Y_i N_{fissions,i} / \varepsilon_{99} f_{99} Y_{99} N_{fissions,i}}{\varepsilon_i f_i Y_{iT}^{U235} N_{fissions,T} / \varepsilon_{99} f_{99} Y_{99T}^{U235} N_{fissions,T}}$$

$$R_{99} = \frac{Y_i / Y_{99}}{Y_{iT}^{U235} / Y_{99T}^{U235}}$$

Efficiencies depend on detector, sample preparation, geometry. Gamma ray abundances also depend on literature values, internal conversion coefficients, etc.

- G.P. Ford and A.E. Norris, LA-6129, 1976
- H.D. Selby, et al., Nucl Data Sheets 111, 2891 (2010)
- M.B. Chadwick, et al., Nucl Data Sheets 111, 2923 (2010)

ENDF R-values



Fission R-values (NCERC)

Objectives

Restore and expand the capability to experimentally measure fission product yields (Y_i).

- We have not conducted these type of experiments in over 40 years.
  - We need to train the next generation of nuclear and radiochemists.
  - New missions require improved inter-laboratory calibrations.
- New high quality nuclear data
  - Validate and cross calibrate current fission bases (e.g. K-factors, R-values)
  - Improve nuclear data sets (Fission Yields (Yi), Cross-sections (σ_x), Endpoint R-values, K-factors, ENDF, JEFF, and JENDL

Measurements to Date

- Comet/ZEUS – September 2011
  - Irradiated U(93), DU and WG-Pu foils
  - Chemistry -> R-values + actinide isotopics
- Comet/ZEUS – Sept/Dec 2012
  - Irradiated U(93) and DU foils (NO Pu)
  - Chemistry -> R-values + actinide activations and isotopics
- Godiva – January 2013 and June 2013
  - 235U and 238U Fission Products as f(time)
- Flattop – June 2013
  - Irradiated U(93) and DU and 233U
- Flattop – August 2014
  - Irradiated U(93) and DU and 237Np
- Flattop – April 2015
  - Irradiated U(93) and DU and 239Pu
- Flattop – June 2015
- Godiva – January 2016

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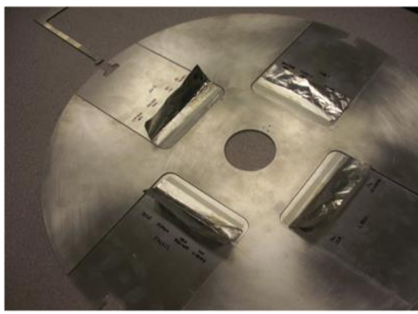
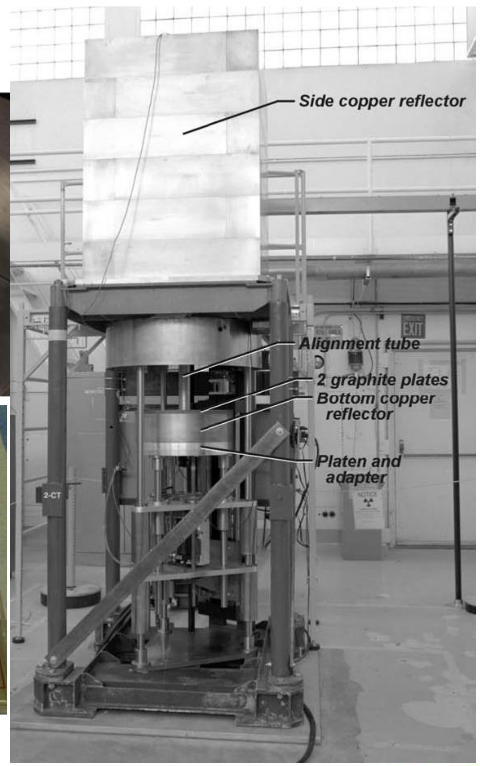
Critical Assemblies

Comet/ZEUS

- General purpose vertical lift assembly
- Configured with the ZEUS reflector
- Used various stackings of the Jemima plates

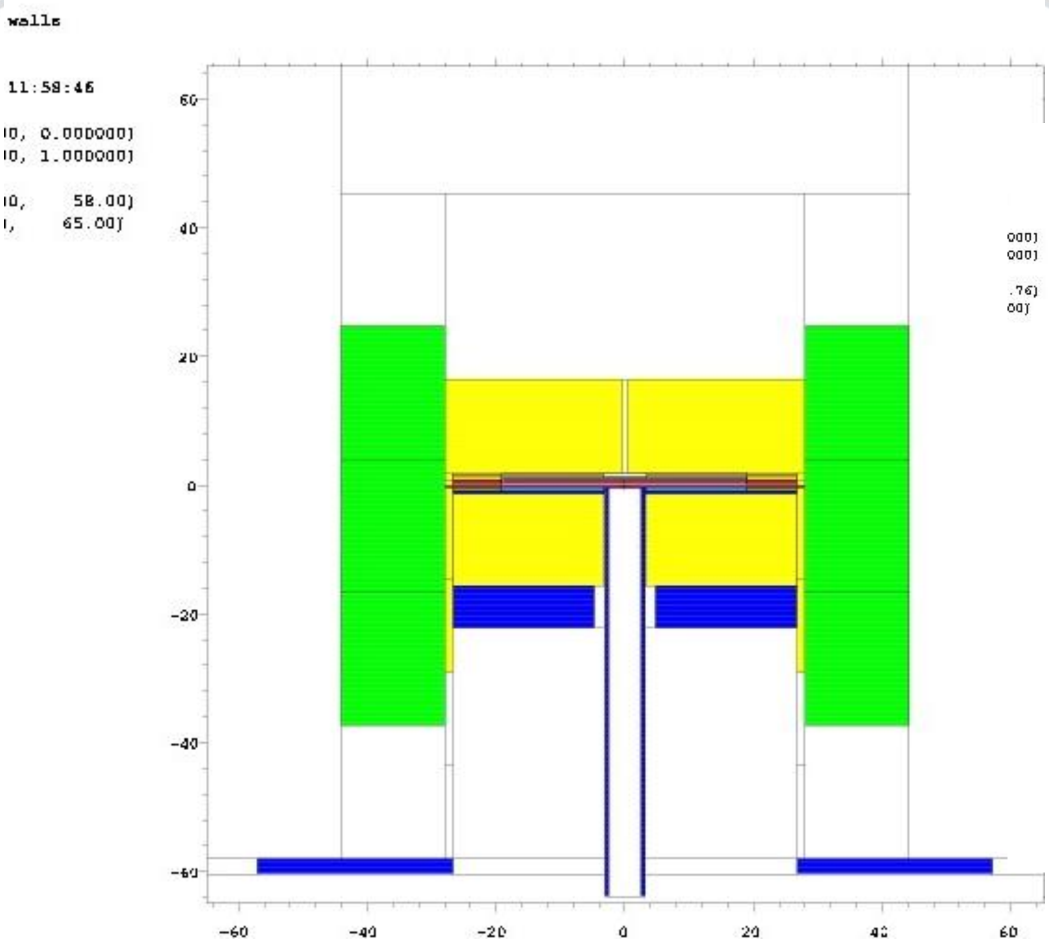


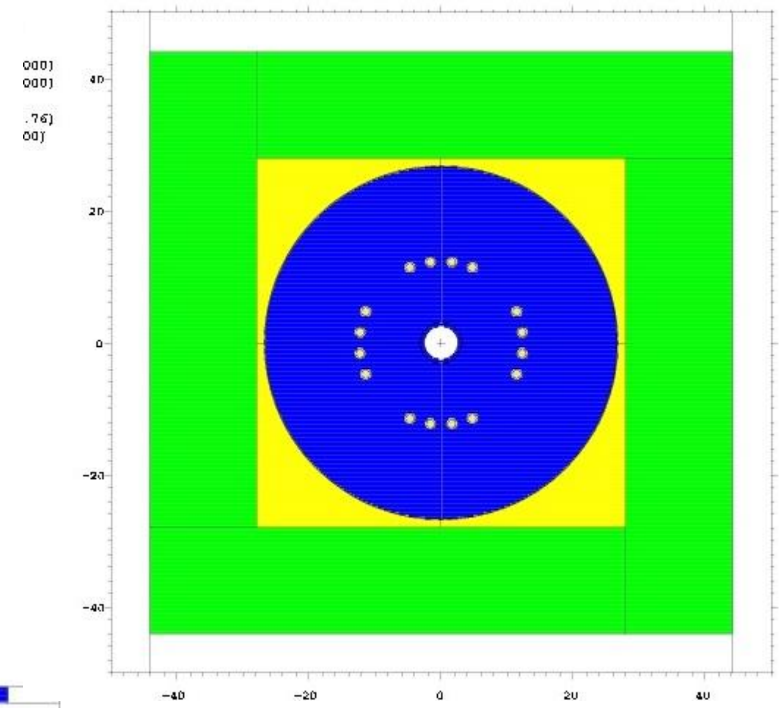


Flattop

- Fast/Fission-spectrum
- HEU and Pu cores / Natural U reflector
- Reactivity increases as parts of spheres brought together and control rods inserted
- Samples inserted in a horizontal “traverse” or glory hole
- ~10^{11} total fissions/g (1.5 hours high power)

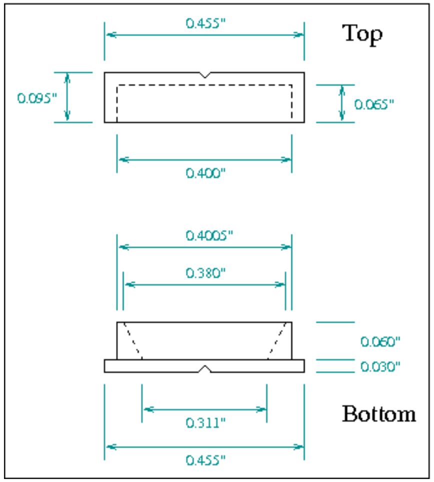
Comet Configuration

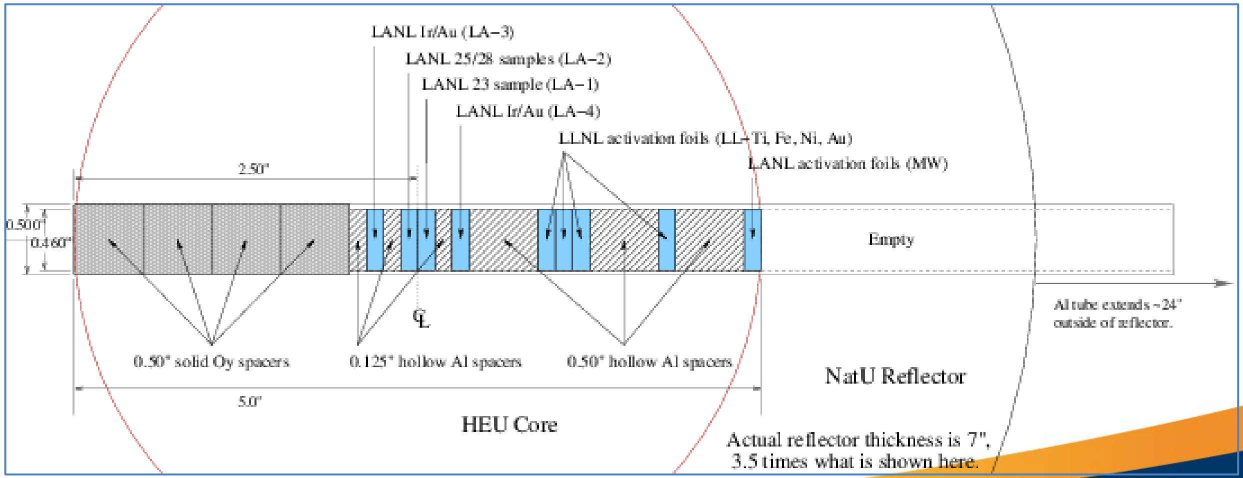




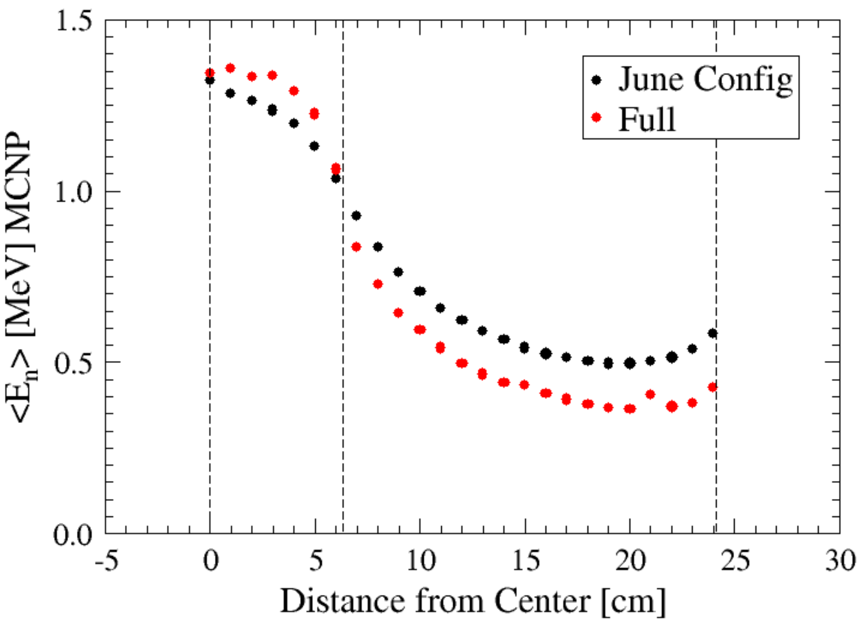
Configuration for Flattop Runs

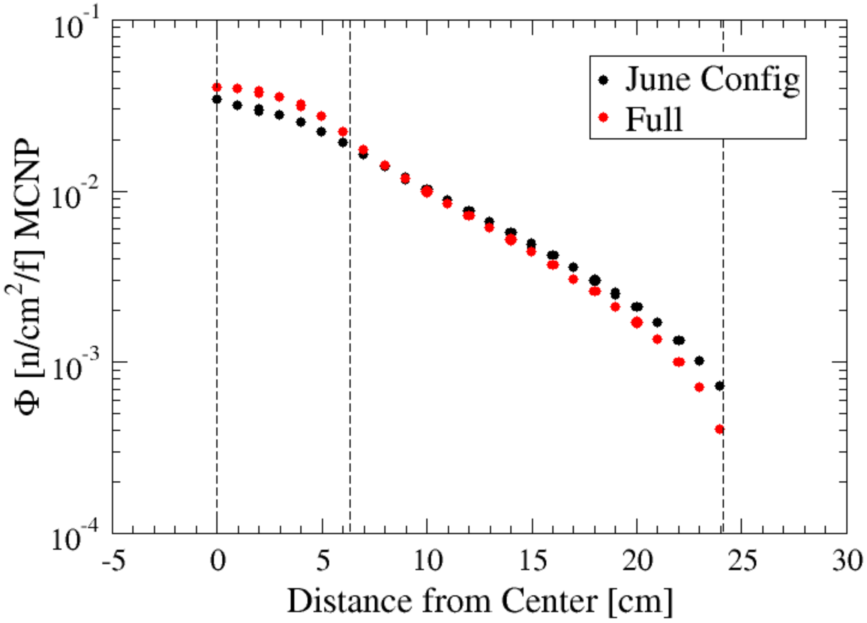
- **Sample containment**
  - All samples/foils were contained in aluminum sample holders (capsules) for easy handling.
  - Design was driven by containment requirements for Pu samples.
  - Exploring other options!
- **Sample recovery**
  - Capsules were stacked inside a three foot long, thin walled aluminum tube for efficient recovery.
  - ¼, ½, and 1 inch hollow aluminum spacers allowed "precise" positioning in the traverse.





Impact On Neutron Flux and Energy MCNP Modeling





- **Mean neutron energy**
  - Remains relatively flat near the center of the core in the full configuration.
  - Immediately begins to drop off with the sample recovery tube.
- **Total neutron flux**
  - The model shows surprisingly little variation between the two configurations.

R-Value Summary

- R-111 has been confirmed as an accurate measure of neutron energy.
- Good agreement with historical R-Values has been obtained.
- These data suggest that fission products that are more sensitive to the neutron spectrum can also be detected (i.e. 111Ag, 115Cd, 153Sm, 156Eu).
- The results demonstrate capability for using fission product analysis to characterize a neutron spectrum.

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